heat stress

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Heat stress is a combination of direct environmental variables (mainly temperature and humidity), work rate and clothing requirements. These factors combine with indirect acclimatization and physical conditions to increase body temperature and cardiovascular demands. Acclimatization to heat involves a series of physiological and psychological adjustments that occur in an individual during the first week of exposure to hot environmental conditions. Extra caution must be taken when workers who are not acclimated or physically fit must be exposed to heat stress conditions. The greater the heat stress is on these workers, the greater the resulting physiological strain. Heat stress can diminish performance and adversely affect health and safety. Most heat-related injuries can be avoided if people are aware of their environment and can recognize heat stress symptoms.

The three types of heat-induced illnesses include heat strain, heat exhaustion,and heatstroke. Transition from one to the next can be very evident, hardly noticeable, or not evident at all.

Heat strain is when the body temperature is between 99.5 and 100 degrees Fahrenheit. It reduces performance, dexterity, coordination, and alertness. Incidence and severity will vary among people.

Heat exhaustion is when the body temperature is between 101 and 104 degrees Fahrenheit. It may cause fatigue, nausea/vomiting, cramps, rapid shallow breathing, and fainting. The skin is pale, cool, clammy, and moist with profuse sweating, and the pulse rate is weak. In its most serious form, heat exhaustion leads to prostration and can cause serious injuries.

Heatstroke is when the body temperature is greater than 104 degrees Fahrenheit. It is the most serious heat-induced illness because of its potential to be life threatening or result in irreversible damage. Heatstroke results from the body losing its ability to lower its temperature. The heatstroke victim is often manic, disoriented, confused, delirious or unconscious. The victim's skin can be hot and dry because sweating has ceased. If treatment is not immediate, the victim's condition can deteriorate to convulsions, brain damage, and eventual death. Immediate emergency care and hospitalization are essential if signs of heatstroke develop. Cool down by any method available and transport to the nearest medical facility for treatment.

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Assessment of heat stress can be conducted by measuring the physical factors of the environment. The commonly used area monitoring measurement is Wet Bulb Globe Temperature (WBGT). This index relates atmospheric effects to heat stress in outdoor and harsh industrial environments.

Physics of Heat

According to thermodynamics, and a great deal of paraphrasing, heat is transferred in three ways: radiation, convection, and conduction.

Radiation — This refers to heat that is exchanged from distant objects (like solar radiant heat or a heater in a room). Certain objects, depending on color and composition, retain and continue to radiate heat (like asphalt, rocks, or dark clothing).

Convection — This refers to the relative movement of air that increases heat exchange. This method is used in convection ovens to cook food efficiently and evenly. Air movement when the temperature exceeds body temperature may increase heat stress. Imagine again your convection oven. Fans cannot cool a person when the temperature exceeds 90 degrees Fahrenheit and humidity is greater than 35 percent. Fans have actually caused heat stress when the temperature is above 100 degrees Fahrenheit. During outdoor activity, certain types of clothing limit the relative wind across the skin, restrict evaporation of sweat, and add a layer of trapped air as insulation.

Conduction — This refers to the direct contact with objects allowing heat exchange (i.e., touching a hot iron). Good thermal conductors transfer heat quickly. Sit on a hot metal playground slide wearing shorts and you will clearly understand conduction. Humidity is an environmental factor that makes it "feel hotter." As the relative humidity increases, evaporation is inhibited, reducing the effectiveness of the body's natu

Photo by TSgt Ben Bloker

Photo by TSgt Jack Braden

ral response to heat. This makes it feel much hotter than the actual temperature reflects. Meteorologically speaking, this is the heat index. The heat index, similar to windchill in the winter, establishes an apparent temperature by comparing either temperature/relative humidity (see heat index chart) or temperature/dew point.

As physical activity increases, so does the amount of muscular heat produced in the body core. The more you move and exert yourself, the more heat your muscles produce. This is why one uncontrollably shivers during very cold temperatures, heat exhaustion, or even heatstroke, as the body can no longer maintain a safe core temperature.

Physiological Response to Heat

Skin plays a central role in maintaining a constant body temperature of 98.6 degrees Fahrenheit (37 C) in two ways. First, capillaries in the skin exchange heat with the environment. In hot weather, these capillaries dilate (cutaneous vasodilation), allowing increased blood flow and heat exchange along the surface of the skin through both conduction and convection. Besides sunburn, this is the reason skin appears red during exercise or hot weather. Second, the skin aids in cooling the core temperature through evaporation. When body temperature increases above 98.6 degrees Fahrenheit, the body actively secretes sweat, containing water and salt from sweat glands in the skin, increasing evaporation and heat loss. Similarly, the exchange across the capillaries of the lungs and the release of water vapor through respiration regulate body temperature.

Additionally, the body reacts in several other ways to decrease body core temperature. The body decreases metabolic rate, thereby lowering metabolic heat production in the body core. In hot weather, behavioral reactions decrease internal temperatures. For example, people naturally become lethargic and tend to rest or lie down. This decreases heat production and increases heat loss to regulate body core temperature.

On a normal day, the body loses approximately 2 liters or a 1/2 gallon of water as imperceptible evaporation from the skin or during respiration. During hot weather and during strenuous physical activity, perspiration increases the rate of water loss. As the body loses water, its ability to regulate temperature is greatly affected. On very hot days and during exercise, by the time you recognize the feeling of thirst it may already be too late! You may not be able to overcome your hydration deficit with continued exposure or physical activity. As one becomes more dehydrated, there is not enough water volume in the body for adequate circulation and thermoregulation. Prolonged dehydration can lead to heat exhaustion or even heatstroke, as the body can no longer maintain a safe core temperature.

Prevention

There are several things you can do to prevent heat stress injuries.

Stay hydrated. Drink plenty of fluids 30 to 45 minutes before exercise and then a cupful every 10 to 15 minutes during exercise. Drink non-alcoholic beverages. Water or sports replacement drinks are the best way to replenish your fluid deficit. Alcohol and caffeine will promote dehydration.

Wear light colored, loose fitting clothing. Moisture wicking fabrics will help evaporation and keep you cooler than heavier fabrics that retain heat. Also, wearing a hat and sunglasses will prevent sunburn, making you feel much more comfortable in the outdoors.

Allow yourself time to acclimate to the heat. Gradually build your heat tolerance in warmer weather. It may take several weeks before you can perform moderate to heavy tasks in higher temperatures. A heat-acclimated person may perspire more than twice as much as an unacclimated person, allowing them to better regulate body temperature.

Physical conditioning is very important as to how your body reacts to heat. Individuals with a higher oxygen uptake are more tolerant of heat than those with lower fitness levels. Also, fat is a great insulator. Extremely obese people are six times more likely to suffer heat stroke than thin people.

Finally, avoid the heat whenever possible. Plan your activities to avoid the hottest part of the day or stay in the shade. Limit outdoor activities during humid days (high heat index).

Understanding the physics and physiology of heat is vitally important when it comes to safely enjoying any summertime activity. Be familiar with the symptoms of heat stress disorders and know the proper first aid — for yourself and those around you. Allow time to acclimate to the heat and use proper prevention measures. Now get outside and stay cool.

Heat Index Table

Relative Humidity	Air Temperature (F)										
	70	75	80	85	90	95	100	105	110	115	120
30	67	73	78	84	90	96	104	113	123	135	148
35	67	73	79	85	91	98	107	118	130	143	
40	68	74	79	86	93	101	110	123	137	151	
45	68	74	80	87	95	104	115	129	143		
50	69	75	81	88	96	107	120	135	150		
55	69	75	81	89	98	110	126	142			
60	70	76	82	90	100	114	132	149			
65	70	76	83	91	102	119	138				
70	70	77	85	93	106	124	144				
75	70	77	86	95	109	130					
80	71	78	86	97	113	136					
85	71	78	87	99	117						
90	71	79	88	102	122						
95	71	79	89	105							
100	72	80	91	108							

HEAT INDEX	POSSIBLE HEAT DISORDER
80°F-90°F	Fatigue possible with prolonged exposure and physical activity
90°- 105°F	Sunstroke, heat cramps and heat exhaustion possible
105°F - 130°F	Sunstroke, heat cramps, and heat exhaustion likely, and heat stroke possible
130°F or greater	Heat stroke highly likely with continued exposure

* Heat and humidity affect everybody differently. Several assumptions are used to calculate the Heat Index. The Heat Index assumes that the body is 5 feet 7 inches tall, 147 pounds, caucasian, body temperature at 98.6 degrees, clothed in long trousers and a short-sleeved shirt, in shade, walking at a speed of 3.1 miles per hour, in a breeze of 6 miles per hour, not dripping sweat.

Note: If any of these factors change, e.g., more exertion, more clothing, and/or more weight, the Heat Index will change for that individual. Exposure to full sunshine can increase Heat Index values by up to 15 degrees Fahrenheit.